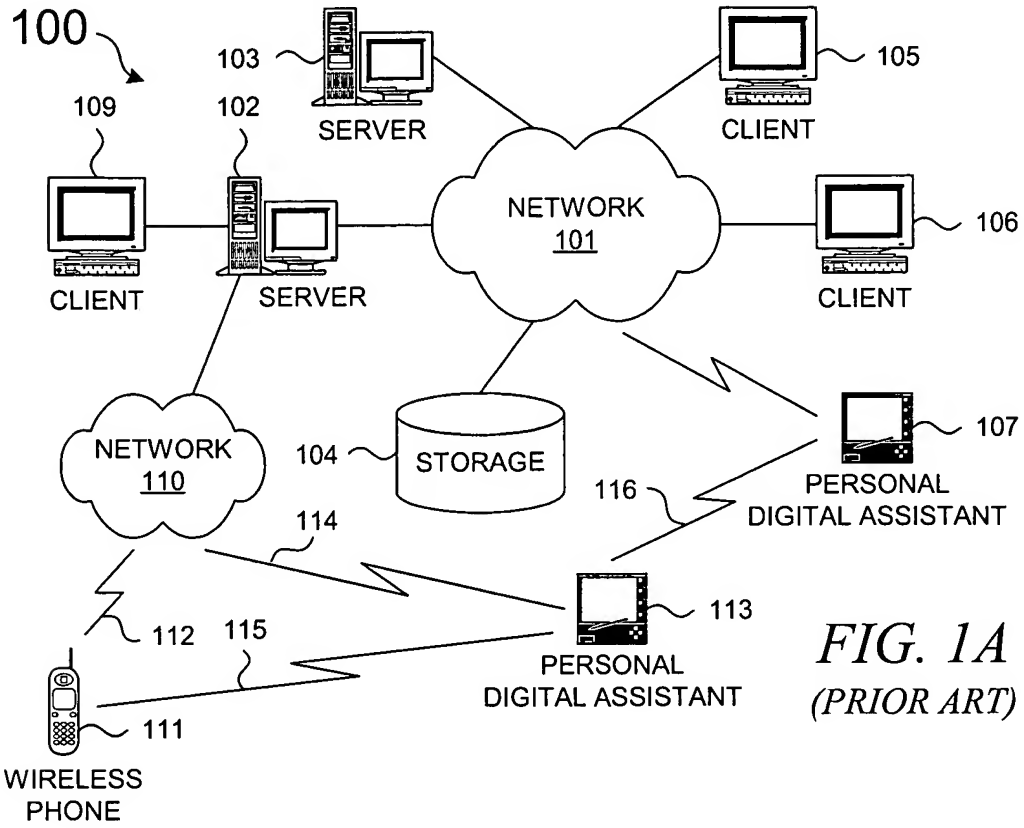

FIG. 1A
(PRIOR ART)

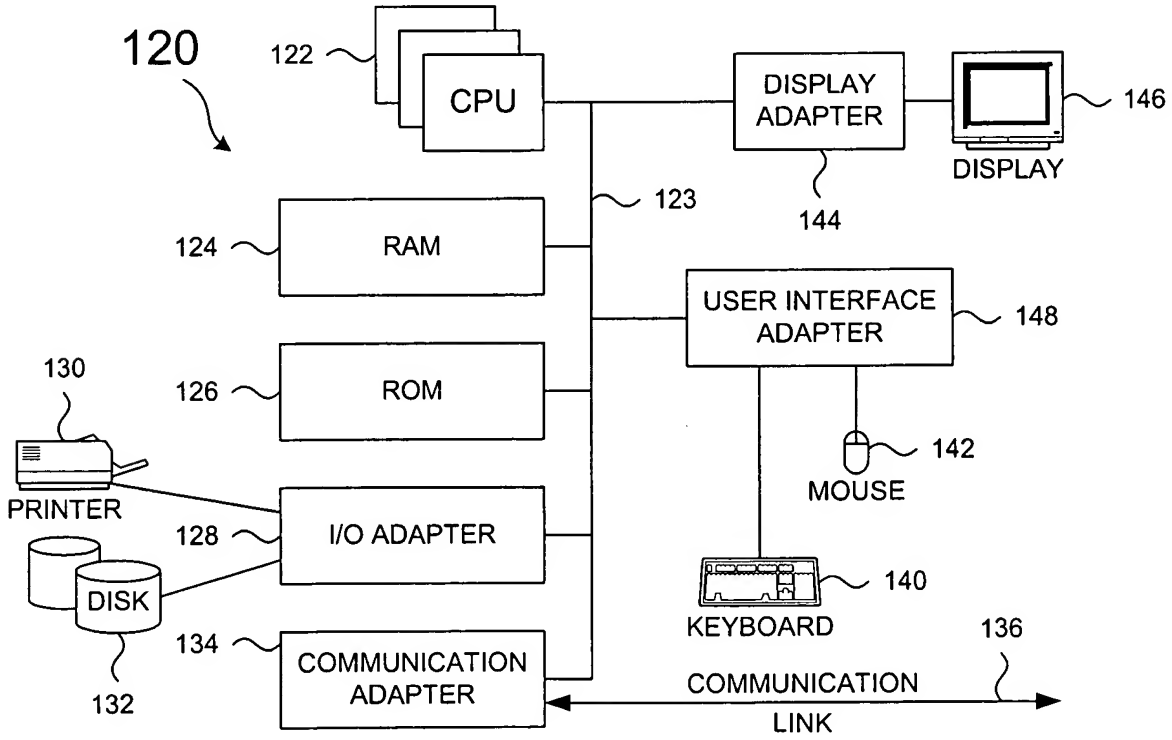

FIG. 1B
(PRIOR ART)

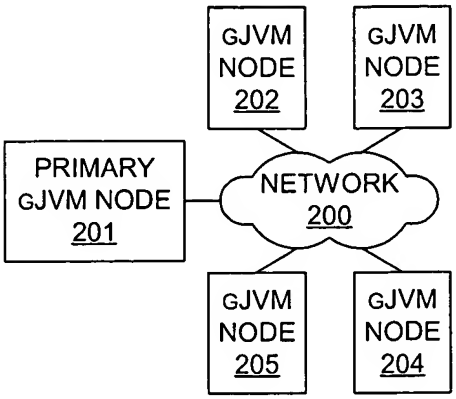
GJVM NODE 202
GJVM NODE 203
PRIMARY GJVM NODE 201
NETWORK 200
GJVM NODE 205
GJVM NODE 204
VIRTUAL MACHINE CLUSTER/GRID

FIG. 2

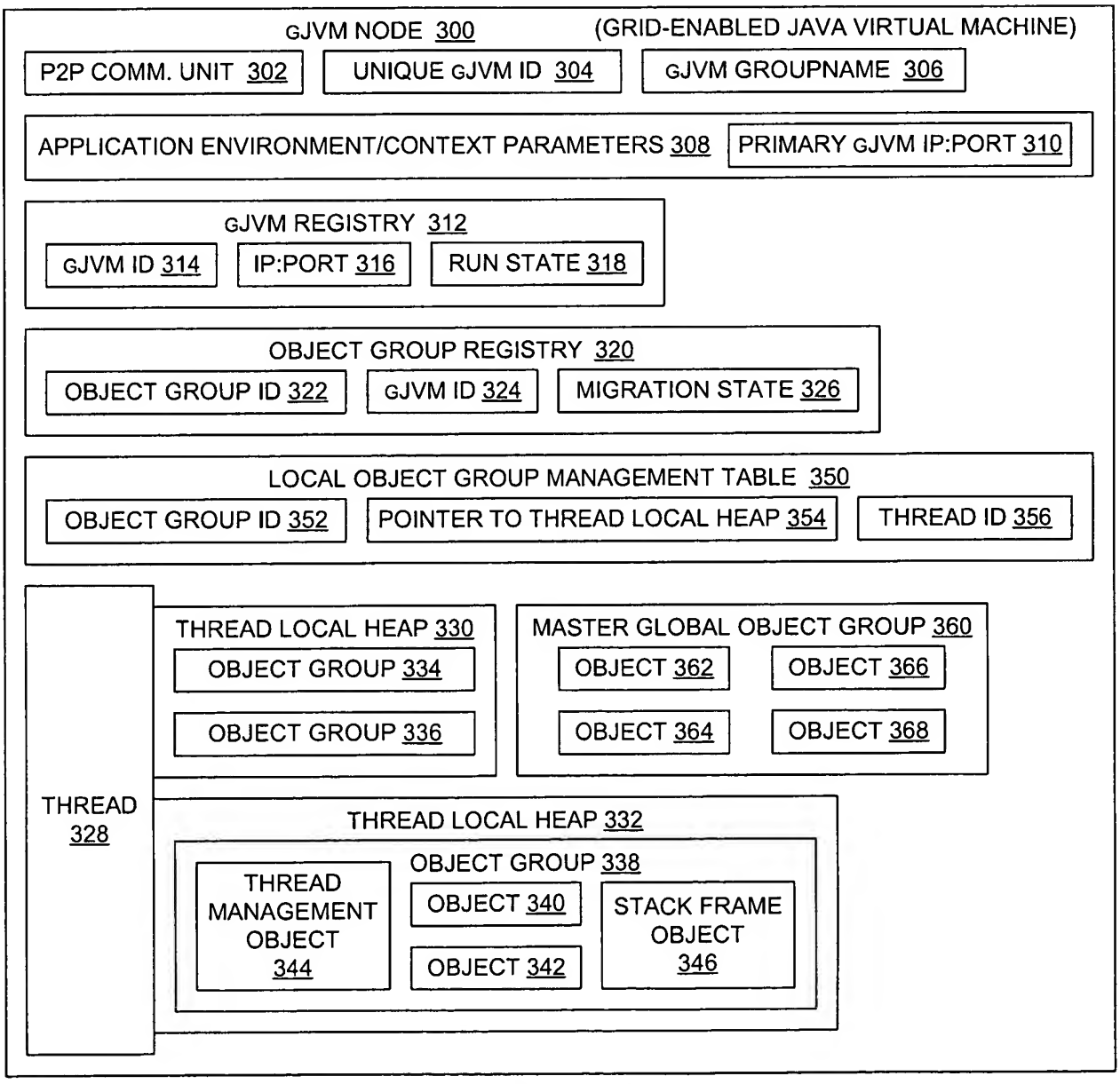
GJVM NODE 300 (GRID-ENABLED JAVA VIRTUAL MACHINE)
P2P COMM. UNIT 302
UNIQUE GJVM ID 304
GJVM GROUPNAME 306
APPLICATION ENVIRONMENT/CONTEXT PARAMETERS 308
PRIMARY GJVM IP:PORT 310
GJVM REGISTRY 312
GJVM ID 314
IP:PORT 316
RUN STATE 318
OBJECT GROUP REGISTRY 320
OBJECT GROUP ID 322
GJVM ID 324
MIGRATION STATE 326
LOCAL OBJECT GROUP MANAGEMENT TABLE 350
OBJECT GROUP ID 352
POINTER TO THREAD LOCAL HEAP 354
THREAD ID 356
THREAD 328
THREAD LOCAL HEAP 330
OBJECT GROUP 334
OBJECT GROUP 336
MASTER GLOBAL OBJECT GROUP 360
OBJECT 362
OBJECT 366
OBJECT 364
OBJECT 368
THREAD LOCAL HEAP 332
OBJECT GROUP 338
THREAD MANAGEMENT OBJECT 344
OBJECT 340
OBJECT 342
STACK FRAME OBJECT 346

FIG. 3A

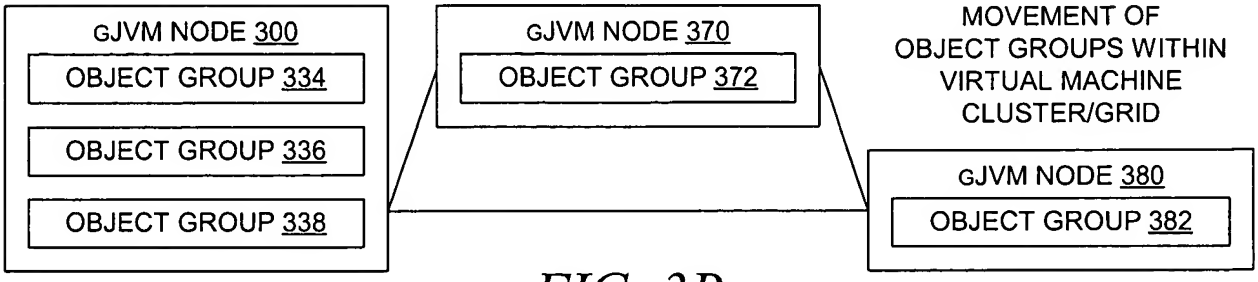

FIG. 3B

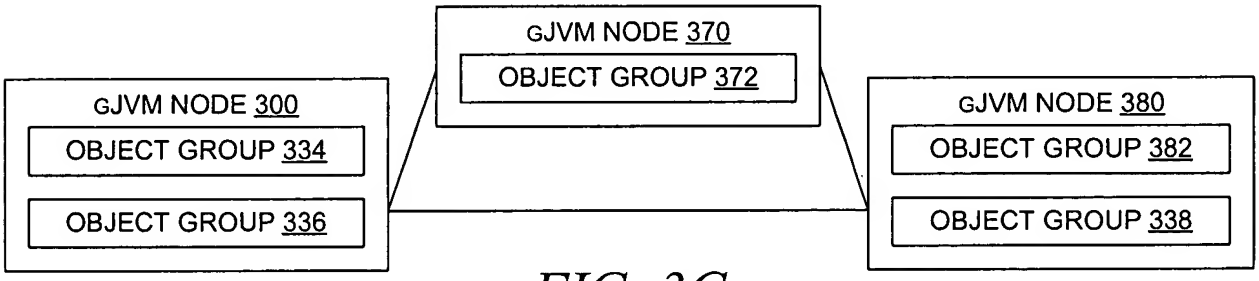

FIG. 3C

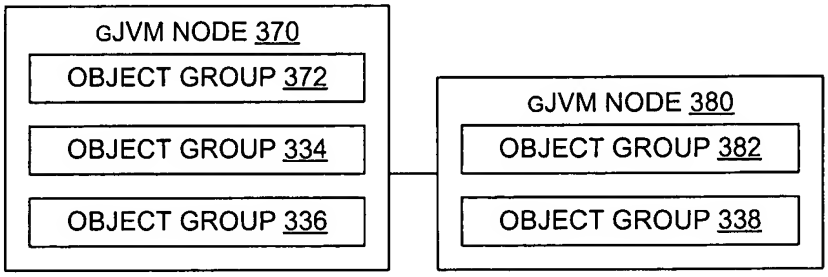

FIG. 3D

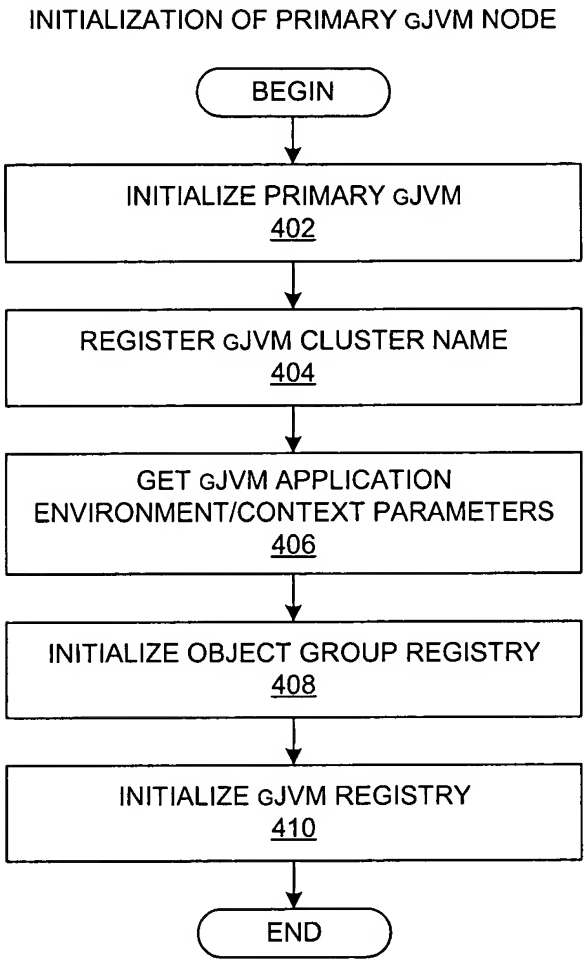
INITIALIZATION OF PRIMARY GJVM NODE
BEGIN
INITIALIZE PRIMARY GJVM
402
REGISTER GJVM CLUSTER NAME
404
GET GJVM APPLICATION
ENVIRONMENT/CONTEXT PARAMETERS
406
INITIALIZE OBJECT GROUP REGISTRY
408
INITIALIZE GJVM REGISTRY
410
END

FIG. 4

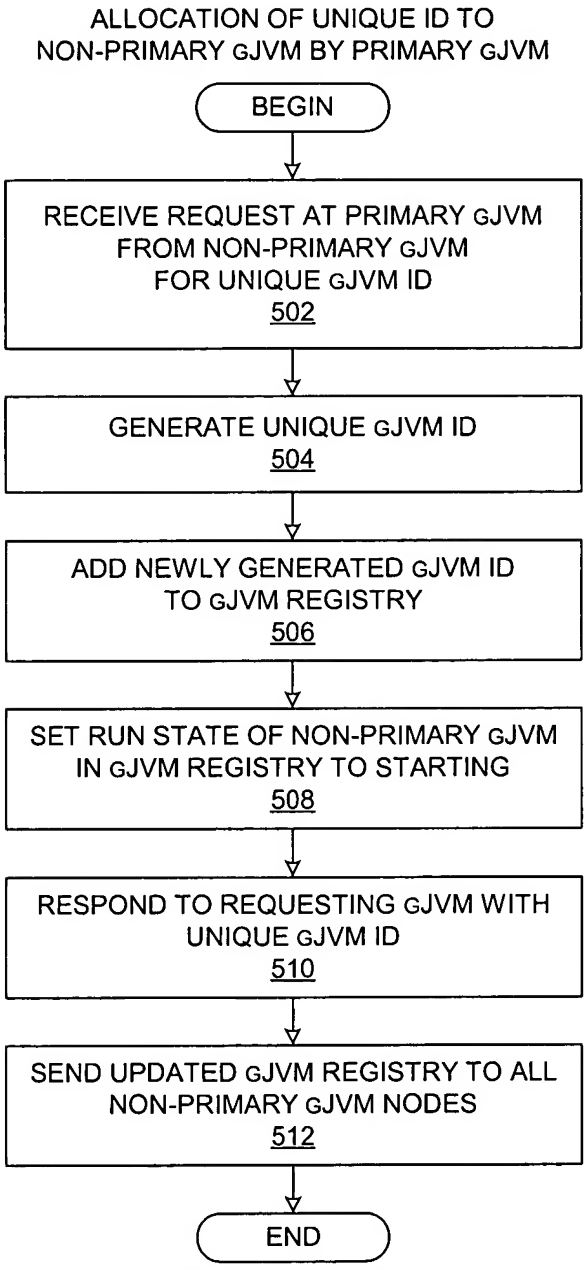
ALLOCATION OF UNIQUE ID TO NON-PRIMARY GJVM BY PRIMARY GJVM
BEGIN
RECEIVE REQUEST AT PRIMARY GJVM FROM NON-PRIMARY GJVM FOR UNIQUE GJVM ID 502
GENERATE UNIQUE GJVM ID 504
ADD NEWLY GENERATED GJVM ID TO GJVM REGISTRY 506
SET RUN STATE OF NON-PRIMARY GJVM IN GJVM REGISTRY TO STARTING 508
RESPOND TO REQUESTING GJVM WITH UNIQUE GJVM ID 510
SEND UPDATED GJVM REGISTRY TO ALL NON-PRIMARY GJVM NODES 512
END

FIG. 5A

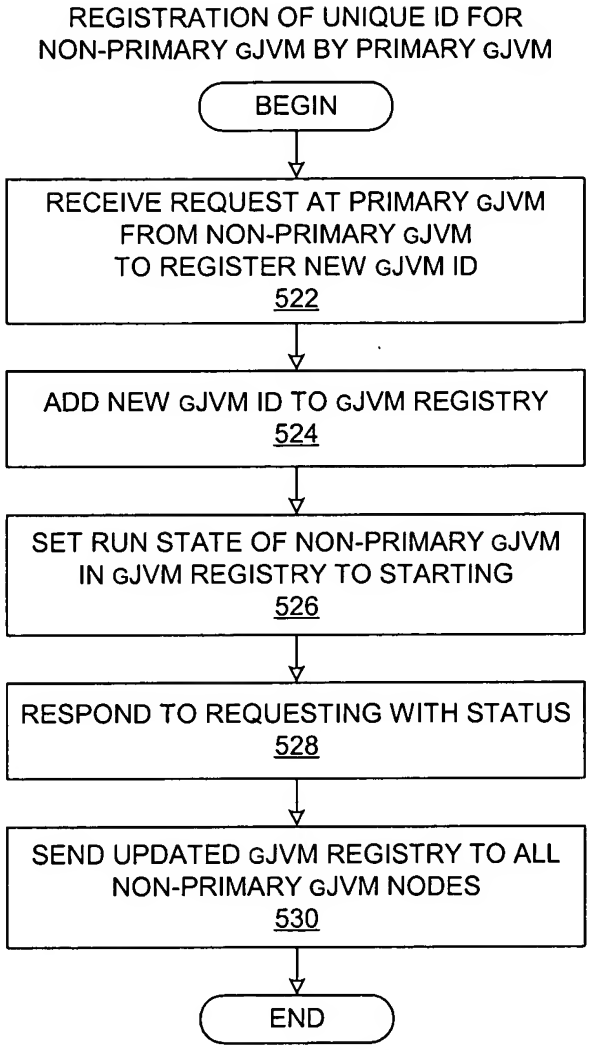
REGISTRATION OF UNIQUE ID FOR NON-PRIMARY GJVM BY PRIMARY GJVM
BEGIN
RECEIVE REQUEST AT PRIMARY GJVM FROM NON-PRIMARY GJVM TO REGISTER NEW GJVM ID 522
ADD NEW GJVM ID TO GJVM REGISTRY 524
SET RUN STATE OF NON-PRIMARY GJVM IN GJVM REGISTRY TO STARTING 526
RESPOND TO REQUESTING WITH STATUS 528
SEND UPDATED GJVM REGISTRY TO ALL NON-PRIMARY GJVM NODES 530
END

FIG. 5B

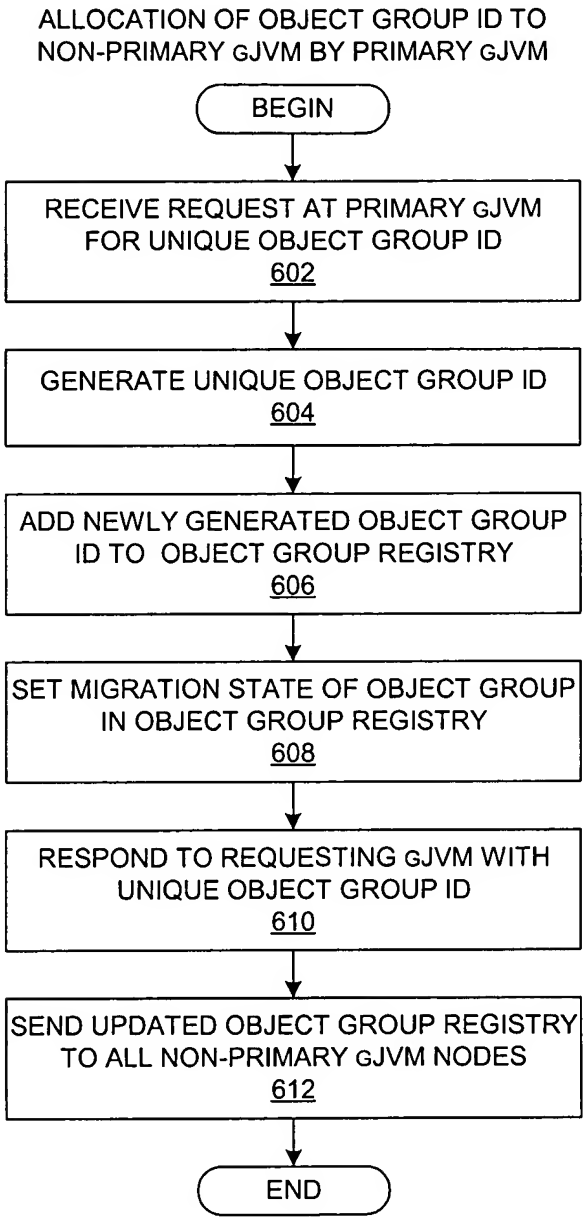
ALLOCATION OF OBJECT GROUP ID TO NON-PRIMARY GJVM BY PRIMARY GJVM
BEGIN
RECEIVE REQUEST AT PRIMARY GJVM FOR UNIQUE OBJECT GROUP ID
602
GENERATE UNIQUE OBJECT GROUP ID
604
ADD NEWLY GENERATED OBJECT GROUP ID TO OBJECT GROUP REGISTRY
606
SET MIGRATION STATE OF OBJECT GROUP IN OBJECT GROUP REGISTRY
608
RESPOND TO REQUESTING GJVM WITH UNIQUE OBJECT GROUP ID
610
SEND UPDATED OBJECT GROUP REGISTRY TO ALL NON-PRIMARY GJVM NODES
612
END

FIG. 6

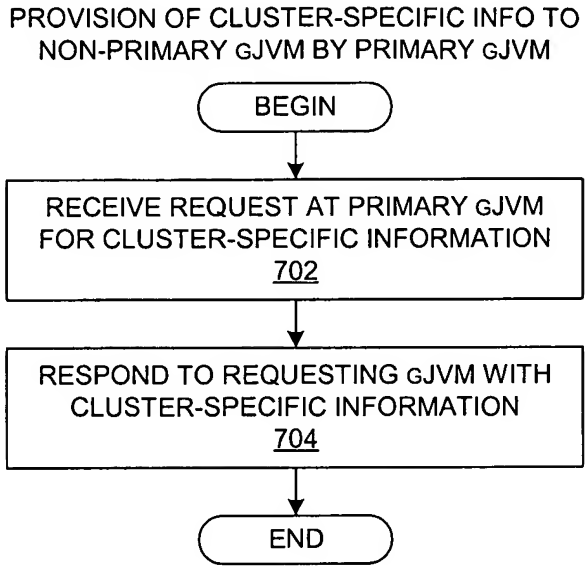
PROVISION OF CLUSTER-SPECIFIC INFO TO NON-PRIMARY GJVM BY PRIMARY GJVM
BEGIN
RECEIVE REQUEST AT PRIMARY GJVM FOR CLUSTER-SPECIFIC INFORMATION
702
RESPOND TO REQUESTING GJVM WITH CLUSTER-SPECIFIC INFORMATION
704
END

FIG. 7

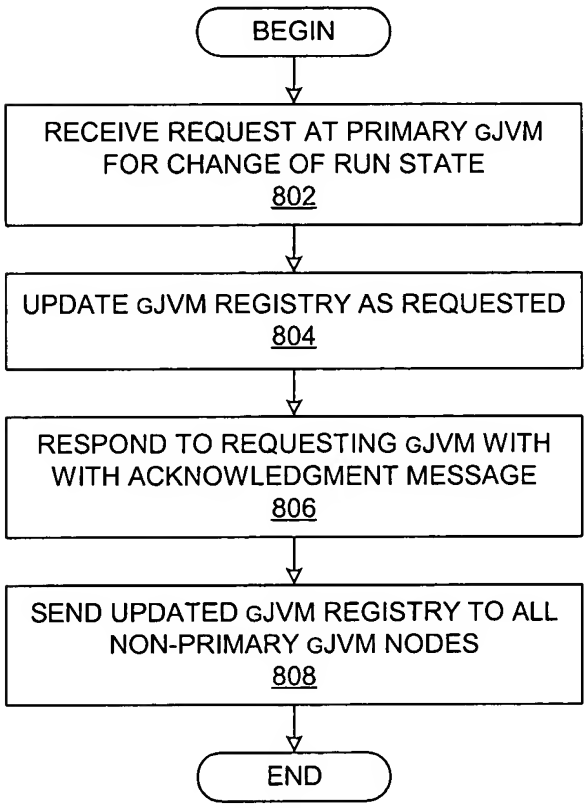
CHANGE OF RUN STATE BY NON-PRIMARY GJVM AT PRIMARY GJVM
BEGIN
RECEIVE REQUEST AT PRIMARY GJVM FOR CHANGE OF RUN STATE
802
UPDATE GJVM REGISTRY AS REQUESTED
804
RESPOND TO REQUESTING GJVM WITH WITH ACKNOWLEDGMENT MESSAGE
806
SEND UPDATED GJVM REGISTRY TO ALL NON-PRIMARY GJVM NODES
808
END

FIG. 8

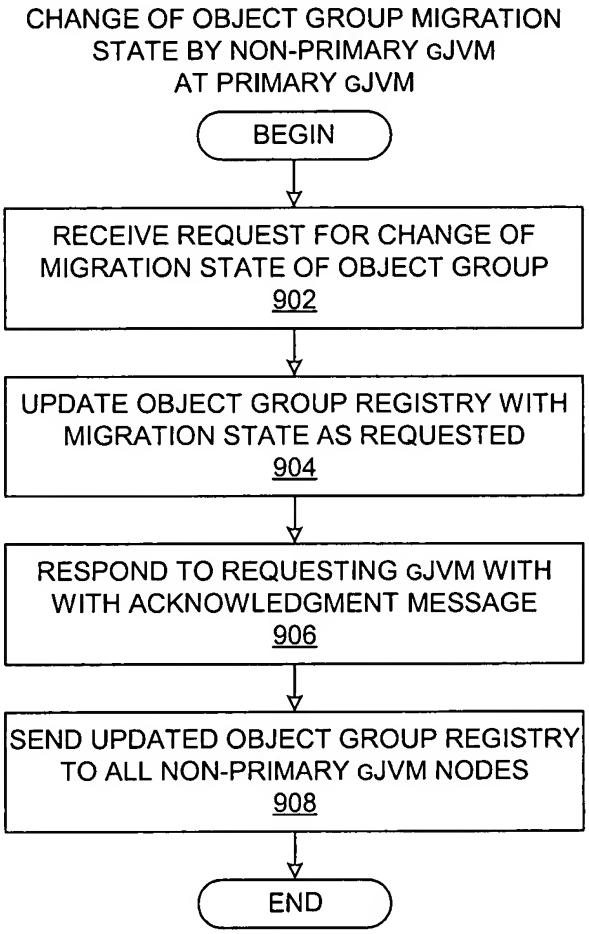
CHANGE OF OBJECT GROUP MIGRATION STATE BY NON-PRIMARY GJVM AT PRIMARY GJVM
BEGIN
RECEIVE REQUEST FOR CHANGE OF MIGRATION STATE OF OBJECT GROUP
902
UPDATE OBJECT GROUP REGISTRY WITH MIGRATION STATE AS REQUESTED
904
RESPOND TO REQUESTING GJVM WITH WITH ACKNOWLEDGMENT MESSAGE
906
SEND UPDATED OBJECT GROUP REGISTRY TO ALL NON-PRIMARY GJVM NODES
908
END

FIG. 9

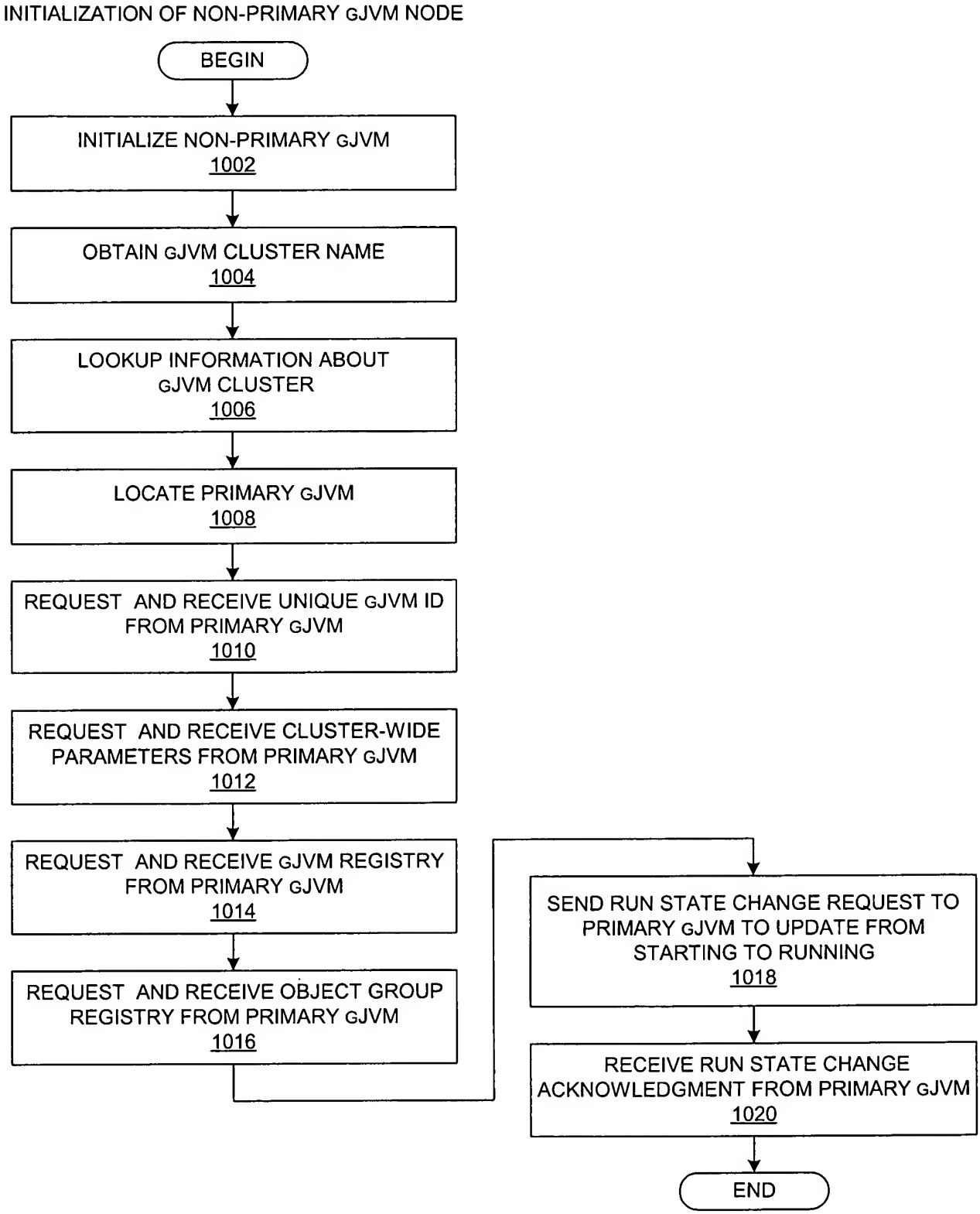
INITIALIZATION OF NON-PRIMARY GJVM NODE
BEGIN
INITIALIZE NON-PRIMARY GJVM
1002
OBTAIN GJVM CLUSTER NAME
1004
LOOKUP INFORMATION ABOUT GJVM CLUSTER
1006
LOCATE PRIMARY GJVM
1008
REQUEST AND RECEIVE UNIQUE GJVM ID FROM PRIMARY GJVM
1010
REQUEST AND RECEIVE CLUSTER-WIDE PARAMETERS FROM PRIMARY GJVM
1012
REQUEST AND RECEIVE GJVM REGISTRY FROM PRIMARY GJVM
1014
REQUEST AND RECEIVE OBJECT GROUP REGISTRY FROM PRIMARY GJVM
1016
SEND RUN STATE CHANGE REQUEST TO PRIMARY GJVM TO UPDATE FROM STARTING TO RUNNING
1018
RECEIVE RUN STATE CHANGE ACKNOWLEDGMENT FROM PRIMARY GJVM
1020
END

FIG. 10

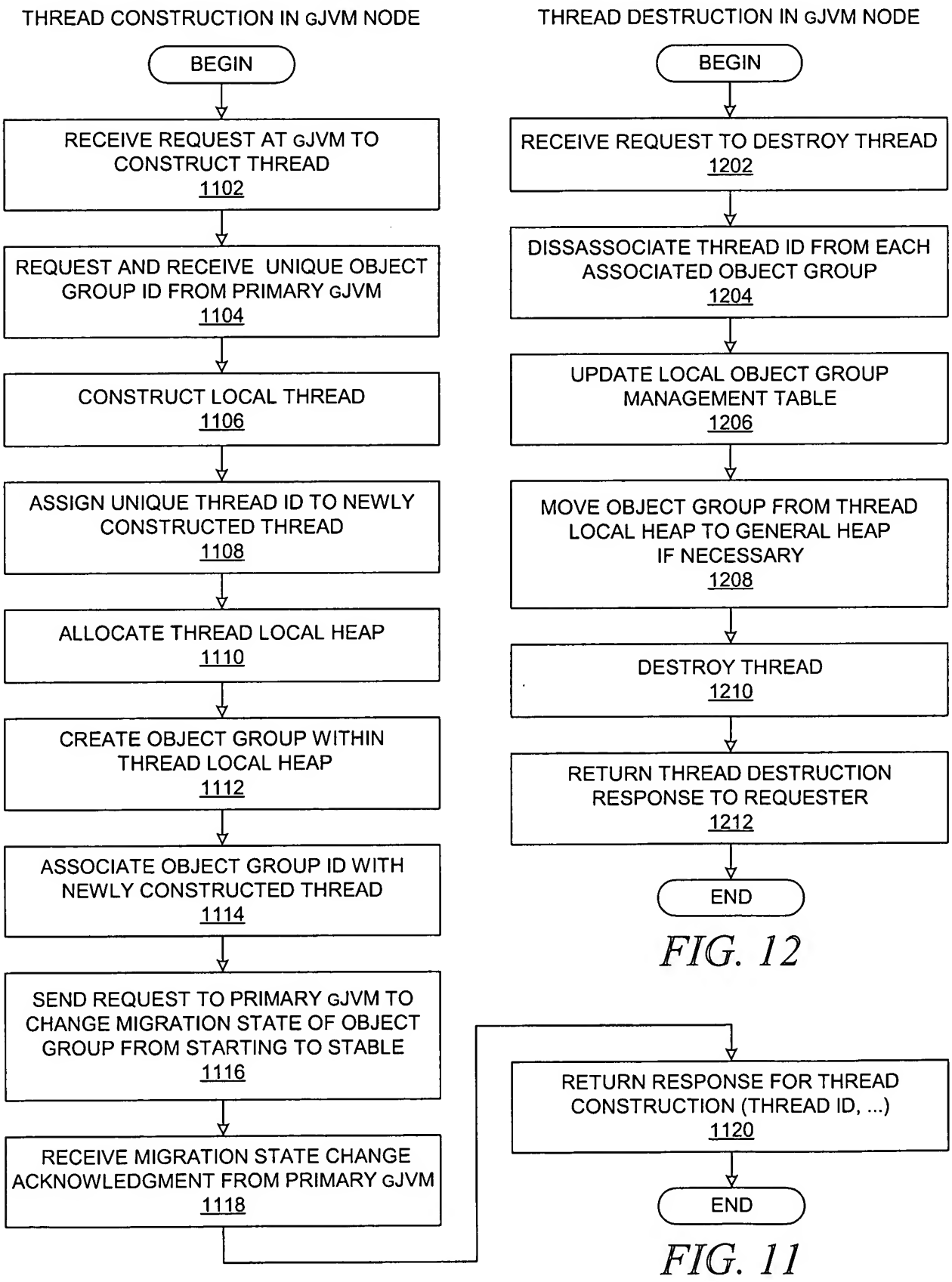
THREAD CONSTRUCTION IN GJVM NODE
BEGIN
RECEIVE REQUEST AT GJVM TO CONSTRUCT THREAD
1102
REQUEST AND RECEIVE UNIQUE OBJECT GROUP ID FROM PRIMARY GJVM
1104
CONSTRUCT LOCAL THREAD
1106
ASSIGN UNIQUE THREAD ID TO NEWLY CONSTRUCTED THREAD
1108
ALLOCATE THREAD LOCAL HEAP
1110
CREATE OBJECT GROUP WITHIN THREAD LOCAL HEAP
1112
ASSOCIATE OBJECT GROUP ID WITH NEWLY CONSTRUCTED THREAD
1114
SEND REQUEST TO PRIMARY GJVM TO CHANGE MIGRATION STATE OF OBJECT GROUP FROM STARTING TO STABLE
1116
RECEIVE MIGRATION STATE CHANGE ACKNOWLEDGMENT FROM PRIMARY GJVM
1118
RETURN RESPONSE FOR THREAD CONSTRUCTION (THREAD ID, ...)
1120
END
THREAD DESTRUCTION IN GJVM NODE
BEGIN
RECEIVE REQUEST TO DESTROY THREAD
1202
DISSASSOCIATE THREAD ID FROM EACH ASSOCIATED OBJECT GROUP
1204
UPDATE LOCAL OBJECT GROUP MANAGEMENT TABLE
1206
MOVE OBJECT GROUP FROM THREAD LOCAL HEAP TO GENERAL HEAP IF NECESSARY
1208
DESTROY THREAD
1210
RETURN THREAD DESTRUCTION RESPONSE TO REQUESTER
1212
END

FIG. 12

FIG. 11

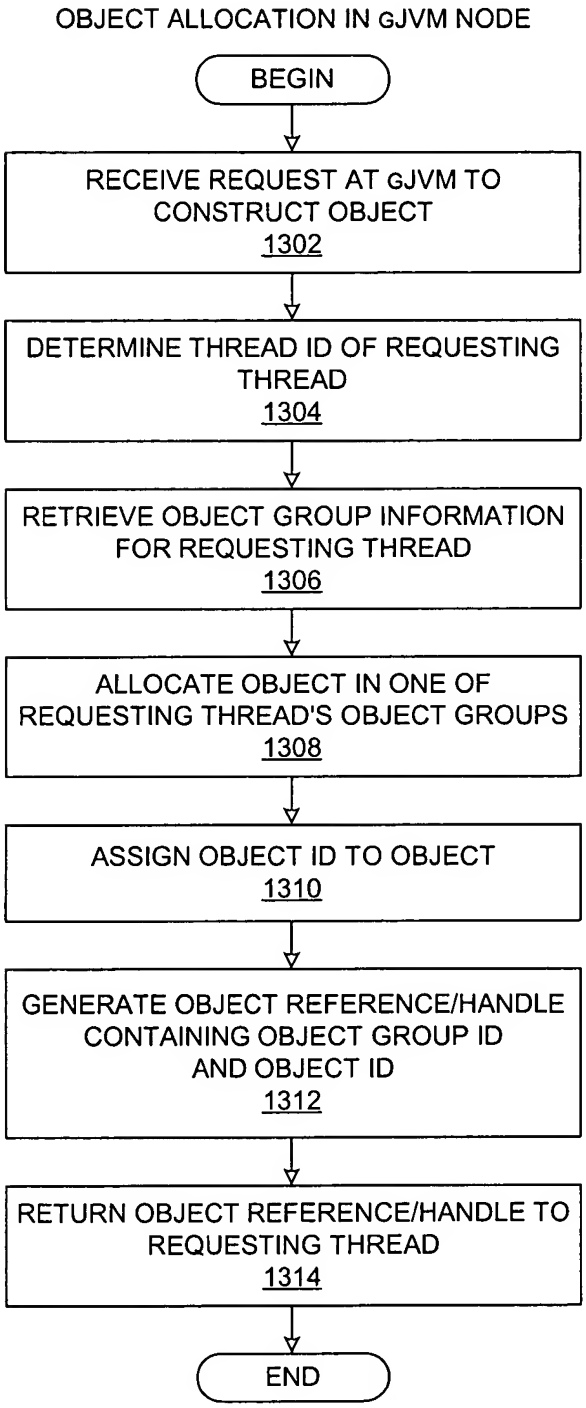
OBJECT ALLOCATION IN GJVM NODE
BEGIN
RECEIVE REQUEST AT GJVM TO CONSTRUCT OBJECT
1302
DETERMINE THREAD ID OF REQUESTING THREAD
1304
RETRIEVE OBJECT GROUP INFORMATION FOR REQUESTING THREAD
1306
ALLOCATE OBJECT IN ONE OF REQUESTING THREAD'S OBJECT GROUPS
1308
ASSIGN OBJECT ID TO OBJECT
1310
GENERATE OBJECT REFERENCE/HANDLE CONTAINING OBJECT GROUP ID AND OBJECT ID
1312
RETURN OBJECT REFERENCE/HANDLE TO REQUESTING THREAD
1314
END

FIG. 13

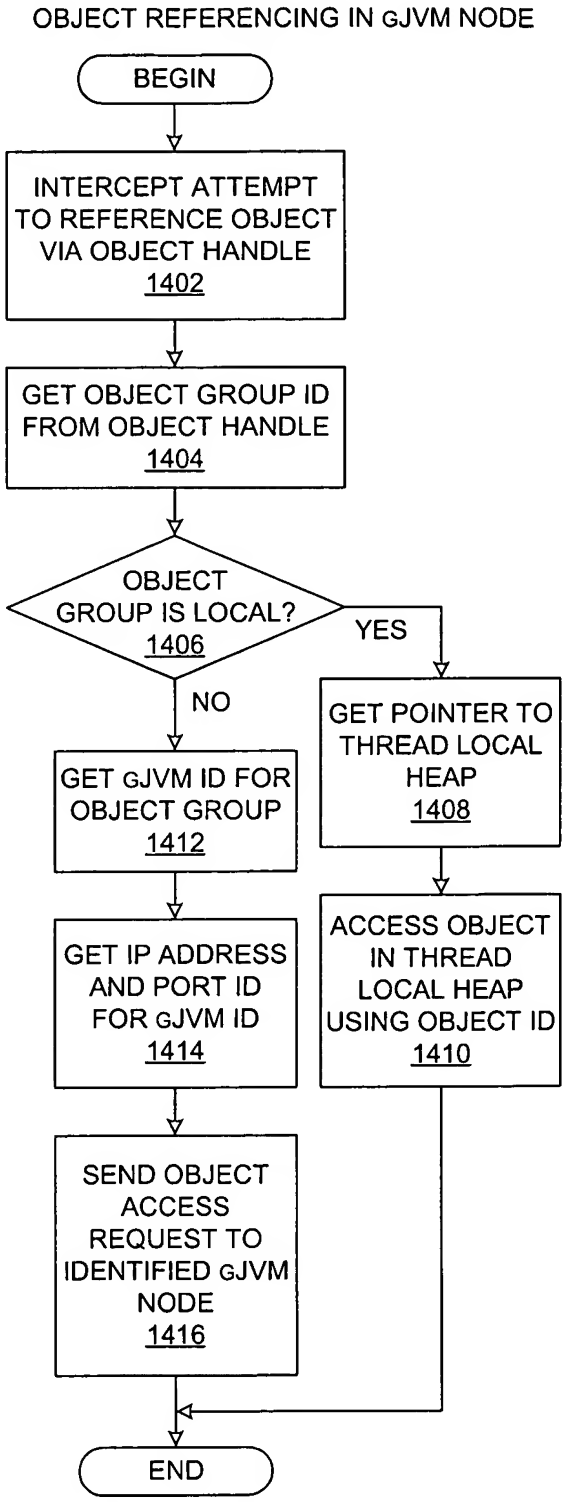
OBJECT REFERENCING IN GJVM NODE
BEGIN
INTERCEPT ATTEMPT TO REFERENCE OBJECT VIA OBJECT HANDLE
1402
GET OBJECT GROUP ID FROM OBJECT HANDLE
1404
OBJECT GROUP IS LOCAL?
1406
YES
NO
GET POINTER TO THREAD LOCAL HEAP
1408
ACCESS OBJECT IN THREAD LOCAL HEAP USING OBJECT ID
1410
GET GJVM ID FOR OBJECT GROUP
1412
GET IP ADDRESS AND PORT ID FOR GJVM ID
1414
SEND OBJECT ACCESS REQUEST TO IDENTIFIED GJVM NODE
1416
END

FIG. 14

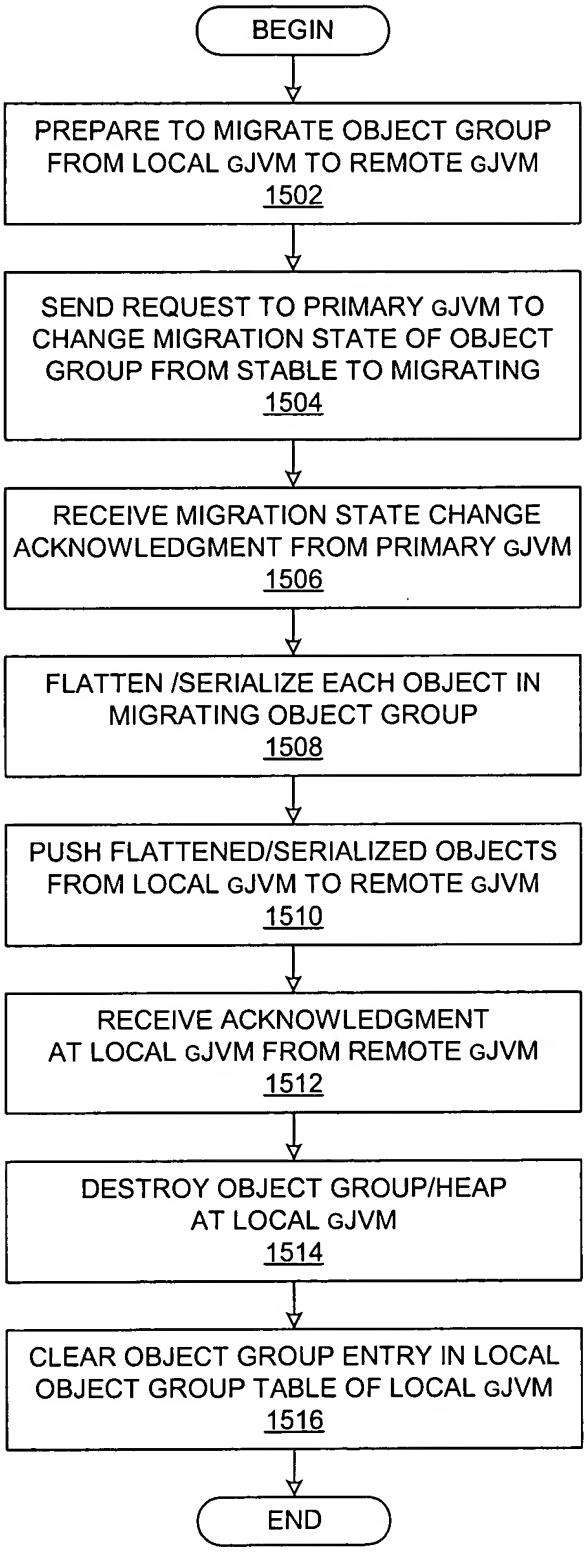
MIGRATION OF OBJECT GROUP FROM GJVM
BEGIN
PREPARE TO MIGRATE OBJECT GROUP FROM LOCAL GJVM TO REMOTE GJVM
1502
SEND REQUEST TO PRIMARY GJVM TO CHANGE MIGRATION STATE OF OBJECT GROUP FROM STABLE TO MIGRATING
1504
RECEIVE MIGRATION STATE CHANGE ACKNOWLEDGMENT FROM PRIMARY GJVM
1506
FLATTEN /SERIALIZE EACH OBJECT IN MIGRATING OBJECT GROUP
1508
PUSH FLATTENED/SERIALIZED OBJECTS FROM LOCAL GJVM TO REMOTE GJVM
1510
RECEIVE ACKNOWLEDGMENT AT LOCAL GJVM FROM REMOTE GJVM
1512
DESTROY OBJECT GROUP/HEAP AT LOCAL GJVM
1514
CLEAR OBJECT GROUP ENTRY IN LOCAL OBJECT GROUP TABLE OF LOCAL GJVM
1516
END

FIG. 15

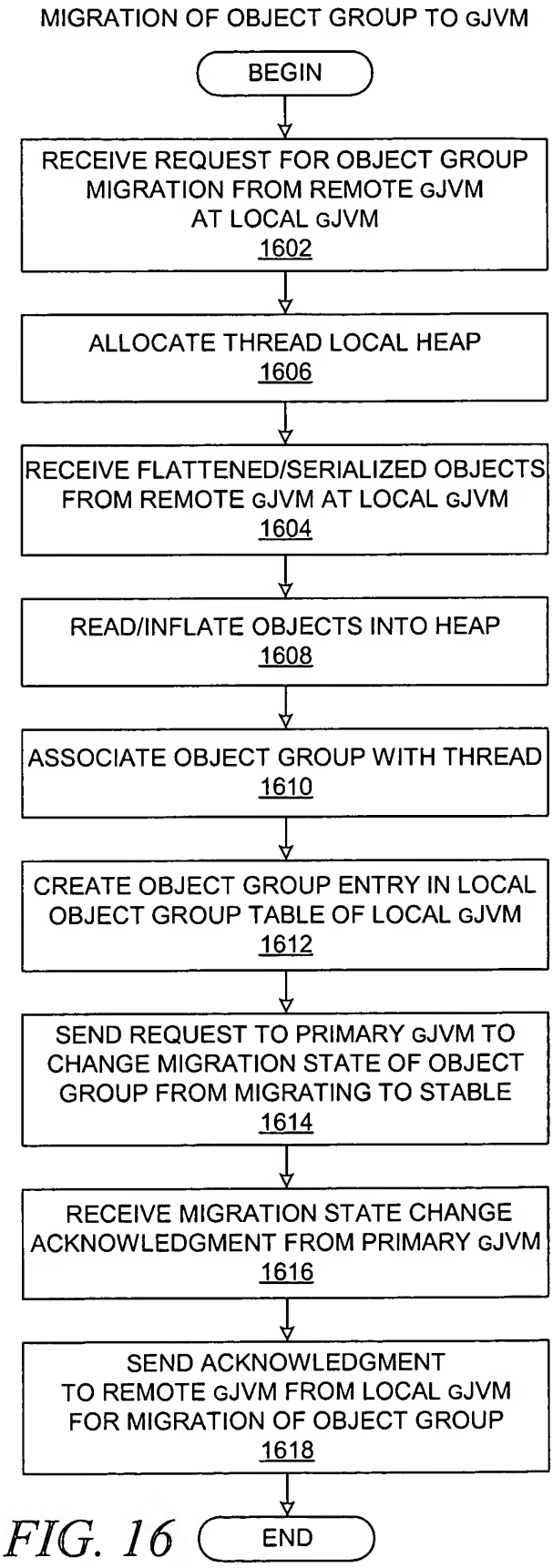
MIGRATION OF OBJECT GROUP TO GJVM
BEGIN
RECEIVE REQUEST FOR OBJECT GROUP MIGRATION FROM REMOTE GJVM AT LOCAL GJVM
1602
ALLOCATE THREAD LOCAL HEAP
1606
RECEIVE FLATTENED/SERIALIZED OBJECTS FROM REMOTE GJVM AT LOCAL GJVM
1604
READ/INFLATE OBJECTS INTO HEAP
1608
ASSOCIATE OBJECT GROUP WITH THREAD
1610
CREATE OBJECT GROUP ENTRY IN LOCAL OBJECT GROUP TABLE OF LOCAL GJVM
1612
SEND REQUEST TO PRIMARY GJVM TO CHANGE MIGRATION STATE OF OBJECT GROUP FROM MIGRATING TO STABLE
1614
RECEIVE MIGRATION STATE CHANGE ACKNOWLEDGMENT FROM PRIMARY GJVM
1616
SEND ACKNOWLEDGMENT TO REMOTE GJVM FROM LOCAL GJVM FOR MIGRATION OF OBJECT GROUP
1618
END

FIG. 16

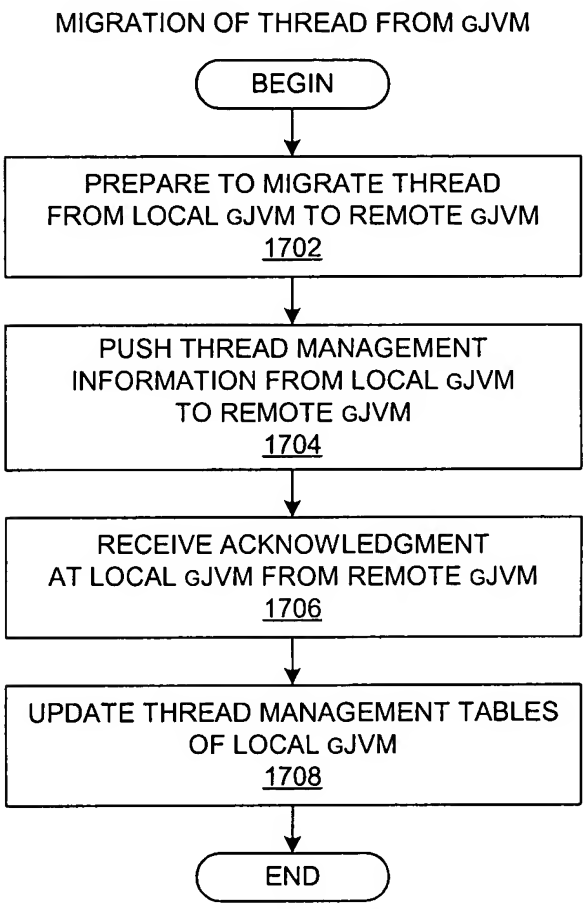
MIGRATION OF THREAD FROM GJVM
BEGIN
PREPARE TO MIGRATE THREAD FROM LOCAL GJVM TO REMOTE GJVM
1702
PUSH THREAD MANAGEMENT INFORMATION FROM LOCAL GJVM TO REMOTE GJVM
1704
RECEIVE ACKNOWLEDGMENT AT LOCAL GJVM FROM REMOTE GJVM
1706
UPDATE THREAD MANAGEMENT TABLES OF LOCAL GJVM
1708
END

FIG. 17

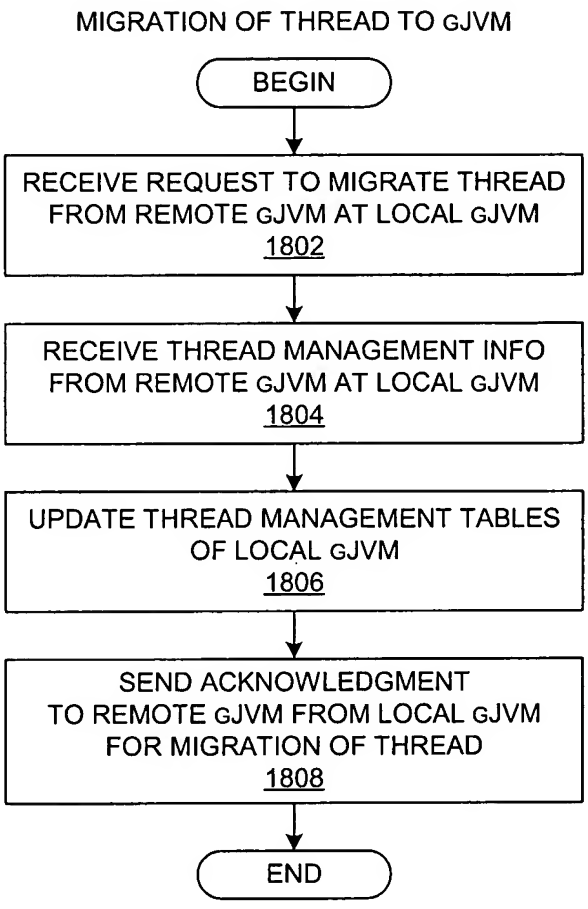
MIGRATION OF THREAD TO GJVM
BEGIN
RECEIVE REQUEST TO MIGRATE THREAD FROM REMOTE GJVM AT LOCAL GJVM
1802
RECEIVE THREAD MANAGEMENT INFO FROM REMOTE GJVM AT LOCAL GJVM
1804
UPDATE THREAD MANAGEMENT TABLES OF LOCAL GJVM
1806
SEND ACKNOWLEDGMENT TO REMOTE GJVM FROM LOCAL GJVM FOR MIGRATION OF THREAD
1808
END

FIG. 18

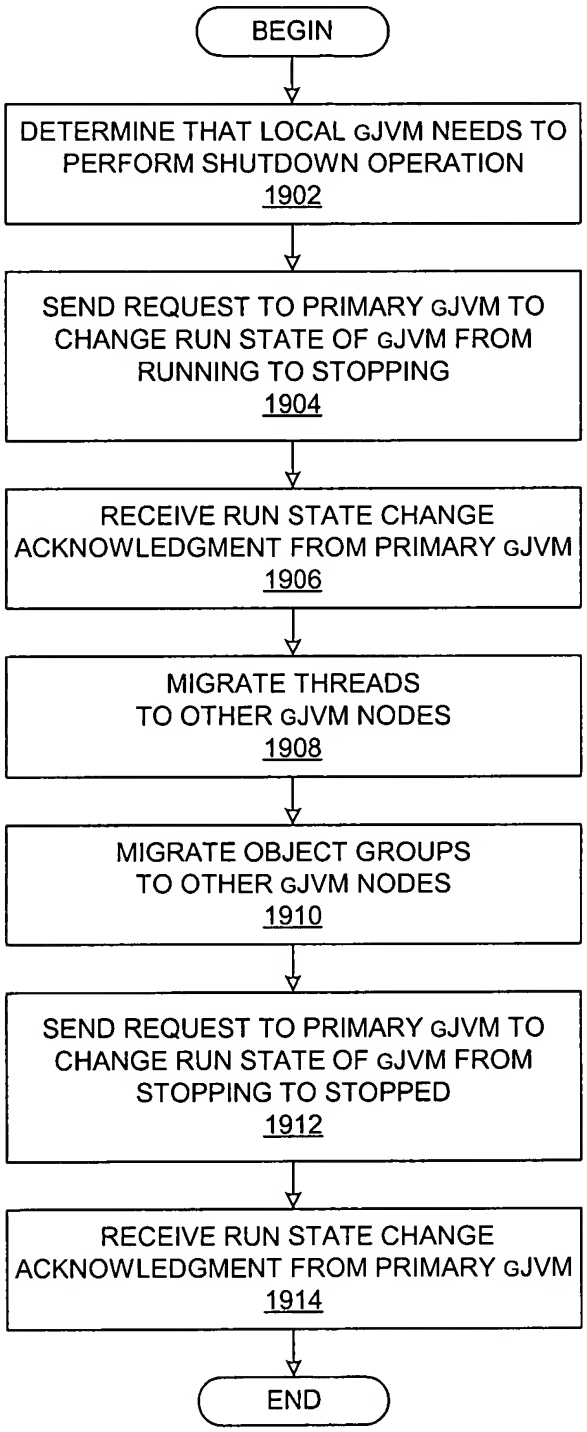
SHUTDOWN OF GJVM NODE
BEGIN
DETERMINE THAT LOCAL GJVM NEEDS TO PERFORM SHUTDOWN OPERATION 1902
SEND REQUEST TO PRIMARY GJVM TO CHANGE RUN STATE OF GJVM FROM RUNNING TO STOPPING 1904
RECEIVE RUN STATE CHANGE ACKNOWLEDGMENT FROM PRIMARY GJVM 1906
MIGRATE THREADS TO OTHER GJVM NODES 1908
MIGRATE OBJECT GROUPS TO OTHER GJVM NODES 1910
SEND REQUEST TO PRIMARY GJVM TO CHANGE RUN STATE OF GJVM FROM STOPPING TO STOPPED 1912
RECEIVE RUN STATE CHANGE ACKNOWLEDGMENT FROM PRIMARY GJVM 1914
END

FIG. 19

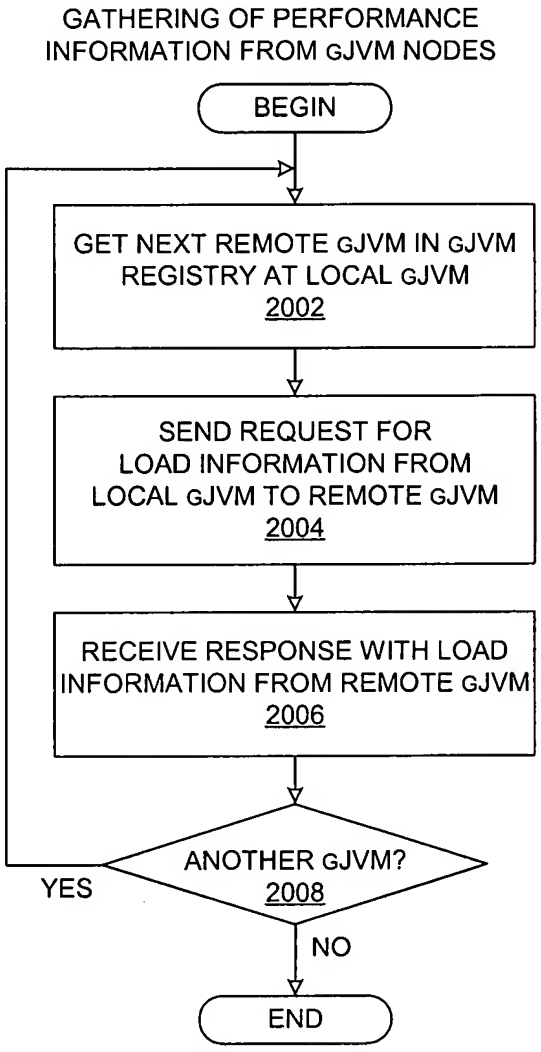
GATHERING OF PERFORMANCE INFORMATION FROM GJVM NODES
BEGIN
GET NEXT REMOTE GJVM IN GJVM REGISTRY AT LOCAL GJVM 2002
SEND REQUEST FOR LOAD INFORMATION FROM LOCAL GJVM TO REMOTE GJVM 2004
RECEIVE RESPONSE WITH LOAD INFORMATION FROM REMOTE GJVM 2006
ANOTHER GJVM? 2008
YES
NO
END

FIG. 20

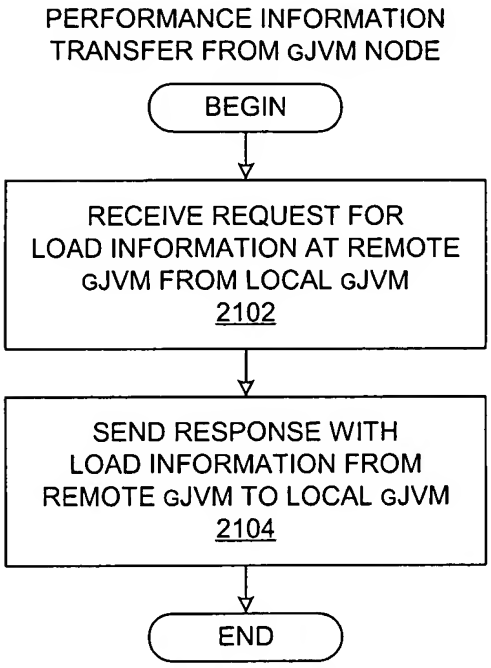
PERFORMANCE INFORMATION TRANSFER FROM GJVM NODE
BEGIN
RECEIVE REQUEST FOR LOAD INFORMATION AT REMOTE GJVM FROM LOCAL GJVM
2102
SEND RESPONSE WITH LOAD INFORMATION FROM REMOTE GJVM TO LOCAL GJVM
2104
END

FIG. 21

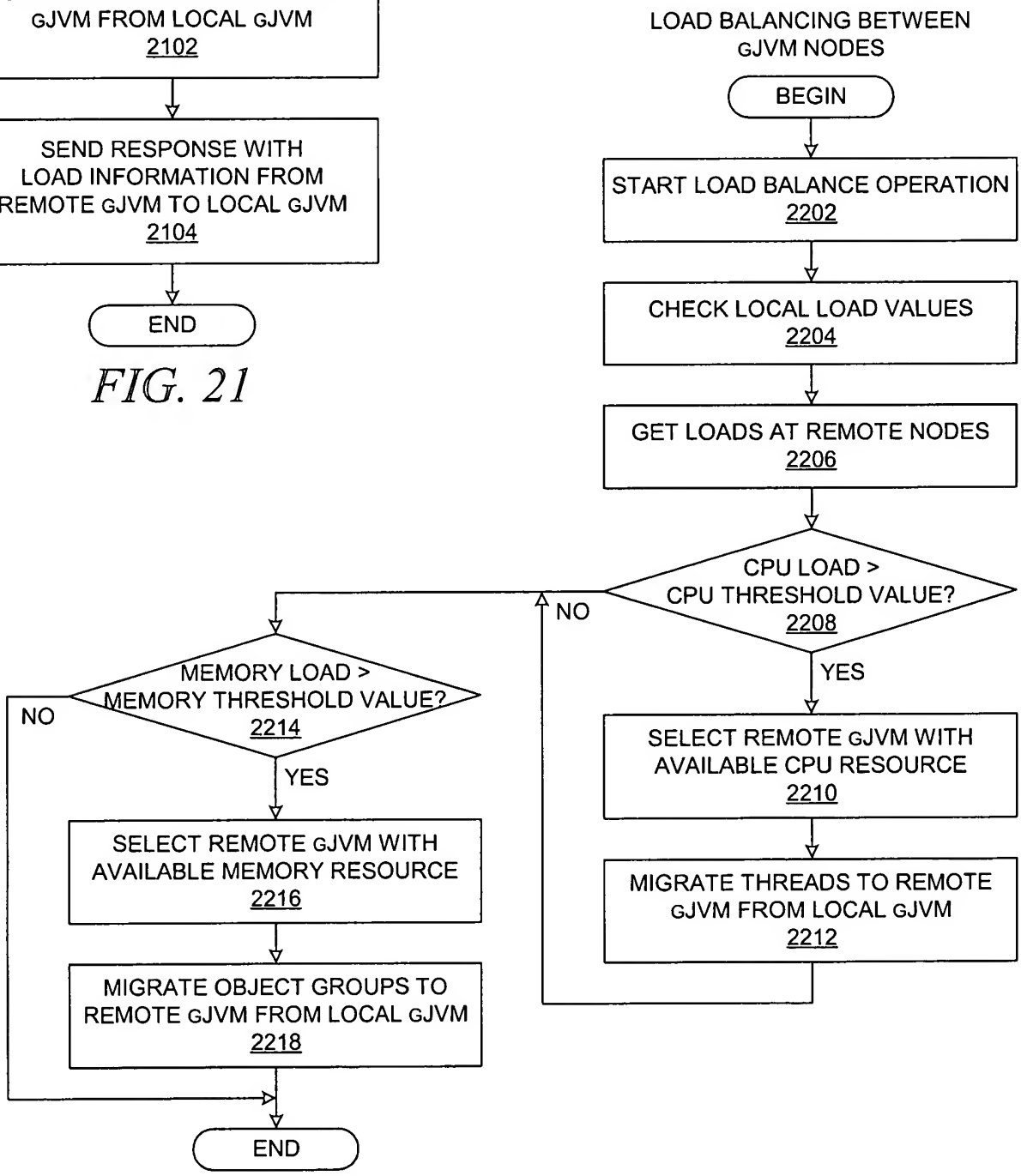
LOAD BALANCING BETWEEN GJVM NODES
BEGIN
START LOAD BALANCE OPERATION
2202
CHECK LOCAL LOAD VALUES
2204
GET LOADS AT REMOTE NODES
2206
CPU LOAD > CPU THRESHOLD VALUE?
2208
NO
YES
SELECT REMOTE GJVM WITH AVAILABLE CPU RESOURCE
2210
MIGRATE THREADS TO REMOTE GJVM FROM LOCAL GJVM
2212
MEMORY LOAD > MEMORY THRESHOLD VALUE?
2214
NO
YES
SELECT REMOTE GJVM WITH AVAILABLE MEMORY RESOURCE
2216
MIGRATE OBJECT GROUPS TO REMOTE GJVM FROM LOCAL GJVM
2218
END

FIG. 22

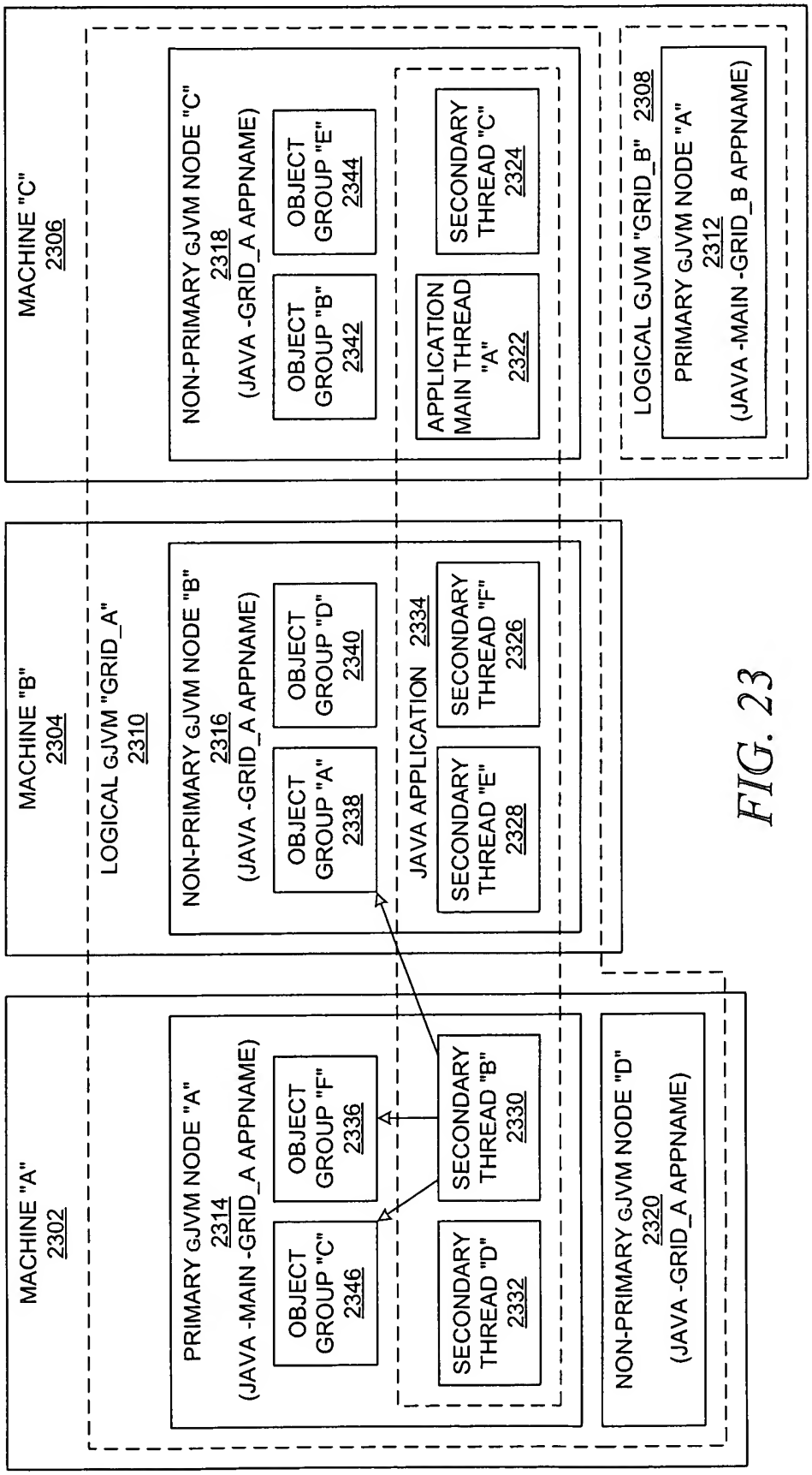
MACHINE "A"
2302
MACHINE "B"
2304
MACHINE "C"
2306
LOGICAL GJVM "GRID_A"
2310
LOGICAL GJVM "GRID_B" 2308
PRIMARY GJVM NODE "A"
2314
(JAVA -MAIN -GRID_A APPNAME)
NON-PRIMARY GJVM NODE "B"
2316
(JAVA -GRID_A APPNAME)
NON-PRIMARY GJVM NODE "C"
2318
(JAVA -GRID_A APPNAME)
NON-PRIMARY GJVM NODE "D"
2320
(JAVA -GRID_A APPNAME)
PRIMARY GJVM NODE "A"
2312
(JAVA -MAIN -GRID_B APPNAME)
JAVA APPLICATION 2334
OBJECT GROUP "A" 2338
OBJECT GROUP "B" 2342
OBJECT GROUP "C" 2346
OBJECT GROUP "D" 2340
OBJECT GROUP "E" 2344
OBJECT GROUP "F" 2336
SECONDARY THREAD "B" 2330
SECONDARY THREAD "C" 2324
SECONDARY THREAD "D" 2332
SECONDARY THREAD "E" 2328
SECONDARY THREAD "F" 2326
APPLICATION MAIN THREAD "A" 2322

FIG. 23